To appear in the February 1967 issue of the Astrophysical Journal

THE REDSHIFT AND ABSORPTION-LINE SPECTRUM OF PKS 0237-23

Bolton has identified a new radio source, PKS 0237-23, measured at Parkes, with a stellar object, and spectra obtained by Arp and Kinman, together with photometry, showed definitely that the source was a quasi-stellar object; the emission lines gave a large redshift (Arp, Bolton, and Kinman 1967).

The striking feature of the optical radiation from PKS 0237-23, apart from its large redshift, is that it has a considerable number of absorption lines in the blue and ultraviolet, reminiscent of 3C 191, the first QSO in which a number of absorption lines were found (Burbidge, Lynds, and Burbidge 1966; Stockton and Lynds 1966). The wavelengths of these lines, measured on Arp's plate taken at Palomar, are given by Arp, Bolton, and Kinman, together with the identifications that they have adopted. Since these identifications seem to pose some problems, it seems appropriate to discuss the question from a different point of view.

A spectrum was obtained on baked IIa-O emulsion with the conventional prime-focus spectrograph on the Lick 120-inch telescope, with the camera-grating combination giving a dispersion of 370 A/mm; this is reproduced in Figure 1. In Table 1 is given a list of the absorption-line wavelengths measured from this plate. Comparison with the list of Arp, Bolton, and Kinman shows reasonable agreement between 3600 Å and 4200 Å, but disagreement at larger wavelengths.

The two emission lines appearing in this spectral range (Ly-α and a blend of O IV] λ1406, Si IV $\lambda\lambda$1394, 1403) are marked in Figure 1, and they give redshifts shown in Table 2, in good agreement with the redshift obtained by Arp, Bolton, and Kinman.

The absorption lines in the spectrum of the quasi-stellar object 3C 191 were easy to identify. With two exceptions, they all arose in absorption from the ground level of ions of the common light elements C, N, Si, and S in ionization stages requiring potentials up to 77 ev (for N V). The two exceptions were absorptions from low-lying metastable levels. The lines were thus what one would expect to be produced in a thin shell absorbing dilute ultraviolet radiation, the shell having a similar composition to that of the region of the QSO producing the emission lines. The strongest absorption lines had also been seen in the rocket ultraviolet spectra of O and B stars (Morton and Spitzer 1966; Morton 1966) and of the sun (Johnson, Malitson, Purcell, and Tousey 1958). The only slightly puzzling feature in 3C 191 was the weakness of the Ly-α absorption line, together with Si II lines of about the same intensity. The ionization potential of H is 13.54 ev and that of Si^{+} is 16.27 ev; if the conditions were such as to cause H to be highly ionized, it was surprising that virtually all the Si^{+} should not have been converted to Si^{++}. This raised the possibility to be kept in mind, that H might be in lower than normal abundance.

In 3C 191, the absorption lines give a redshift very close to that given by the emission lines. In PKS 0237-23, the first thing that strikes the eye is the pair of strong absorption lines at 4116 and 4141 Å. These are quite close to the Si IV lines in 3C 191, with rest wavelengths 1393.8 and 1402.8 Å, which appeared at 4109 and 4135 Å in 3C 191. They are very much stronger, however, and the redshift they would give, 1.9525, very close to that of 3C 191, would differ considerably from the emission-line redshift of 2.224. An attempt to fit the lines with identifications at a redshift of about 1.95 is shown in Table 1. Lines corresponding to unidentified absorption lines near that wavelength in 3C 191 are marked "191". The relative intensities would be different from those in 3C 191, and the weakness of C II and C IV would be hard to understand.

Alternatively, one can look for identifications at a redshift close to the emission-line redshift, and this is the viewpoint taken by Arp, Bolton, and Kinman. Here also, the complete absence of C II λ1335 and C IV λ1549 is striking and could only be explained by their interpretation, that the region producing the absorption lines is highly deficient in carbon. The two strongest lines, λλ4116 and 4141, were identified by them with Ti III. The two multiplets in question, $a^3F-z^3D^o$ and $a^3F-z^3F^o$ (Moore 1950), contain the strong lines 1298.67, 1298.95, 1298.67, 1294.67, 1295.91; 1286.38, 1289.32, 1291.64, 1293.26, 1294.67 Å, which break into three groups at mean wavelengths 1298.75, 1294.30, and 1287.64 Å or else one narrow line at 1298.75 Å and one very broad, strong one centered at 1292.4 Å. It is difficult to fit these possibilities with the two strong observed lines, of which the shorter wavelength one is certainly not broader than the other.

One possibility is that the two strong lines have a redshift very different from the rest, as, for example, if they were produced in intergalactic gas in a cluster as suggested by Bahcall and Salpeter (1966). A search through their list, Osterbrock's (1963) list, and the multiplet tables reveals one strong multiplet with the right spacing: Si II λλ1816.9, 1808.0, and 1817.4, which would combine to two lines and, if they were the correct identification, would give redshifts z = 1.2767 and 1.2789. Of other strong lines at this redshift, C IV λ1549 would be at 3529 Å and Mg II λ2798 at 6373 Å. However, according to Bahcall and Salpeter, one would expect only the transition from the $J = \frac{1}{2}$ level, i.e. λ1808.0, in intergalactic gas, so this interpretation seems unlikely.

There seems to be no identification for the lines at 3865 and 3891 Å at a redshift of 1.95. Possibly the latter might be Ly-α at the redshift near that of the emission line, as suggested by Arp, Bolton, and Kinman.

A search for sets of lines with differing redshifts close to $z \approx 2$, such as might be produced by a series of expanding shells, has not proved fruitful.

The problem of identifications has been discussed here purely from the point of view of normal spectroscopy, and it is seen that none of the possibilities discussed is satisfactory. However, it has been shown (Burbidge 1967) that there are several lines in PKS 0237-23 which lie very close in wavelength to lines in 3C 191, and, using the rest wavelengths of those which are identified in 3C 191, we obtain an absorption-line redshift which is almost exactly that of 3C 191. Moreover the other QSO's with $z > 1.9$ which have absorption lines also show for these lines a closely similar redshift. Thus, despite the puzzling features in PKS 0237-23, it may be reasonable to conclude that the object has an absorption-line redshift of 1.95.

I wish to thank Drs. Arp and Kinman for discussing their spectra and for showing me their list of absorption-line identifications ahead of publication. This work has been supported in part by the NSF and in part by NASA through grant NsG-357.

E. M. BURBIDGE

University of California, San Diego

December 2, 1966

REFERENCES

Arp, H. C., Bolton, J. G., and Kinman, T. D. 1967, Ap. J.

Bahcall, J. N. and Salpeter, E. E. 1966, Ap. J., 144, 847.

Burbidge, E. M., Lynds, C. R., and Burbidge, G. R. 1966, Ap. J., 144, 447.

Burbidge, G. R. 1967, submitted to Ap. J.

Johnson, F. S., Malitson, H. H., Purcell, J. D., and Tousey, R. 1958, Ap. J., 127, 80.

Moore, C. E. 1950, Circ. Nat. Bur. Standards, No. 488, Sec. 1.

Morton, D. C. 1966, A.J., 71, 172.

Morton, D. C. and Spitzer, L. 1966, Ap. J., 144, 1.

Osterbrock, D. E. 1963, Planet. Space Sci., 11, 621.

Stockton, A. N. and Lynds, C. R. 1966, Ap. J., 144, 451.

Table 1

ABSORPTION LINES

	Description	λ Measured Å	One Possible Identification	z
1.	Slightly broad	3444.9	191	
2.	Narrow, weak	3460.7		
3.	Complex from to With main peak at	3499.9 3528.7 3515.7	Si II λ1194.1	1.9442
4.	Fairly narrow	3591.4	Ly-α λ1215.7	1.9542
5.	Slightly broad, strong	3719.4	Si II λ1263.4	1.9440
6.	Narrow	3839.3	(OI λ1304.4)	(1.9433)
7.	Fairly narrow	3865.5		
8.	Fairly strong	3890.7		
9.	Fairly weak	3933.5	C II λ1335.3	1.9457
10.	Medium	3951.8		
11.	Slightly broad, weak	3971.5	191	
12.	Broad, strong	4023.9	191	
13.	Fairly broad, strong	4115.6	Si IV λ1393.8	1.9528
14.	Broad, strong	4140.8	Si IV λ1402.8	1.9518
15.	Medium	4266.6	191	
16.	Fairly narrow, weak	4285.8	191	
17.	Medium	4301.3	191	
18.	Weak	4572.0	C IV λ1549.1	1.9514
19.	Weak	4595.9		
20.	Weak	4612.8		

Table 2

EMISSION LINES

λ Observed (Å)	Identification	λ_0 (Å)	z
3919.8	Ly-α	1215.7	2.2243
4513.7	Si IV	1393.8	
	Si IV	1402.8	
	O IV]	1407.3	
	Mean:	1401.3	2.2211

FIGURE CAPTION

Fig. 1 Spectrum of PKS 0237-23, with two emission lines marked, also most of the absorption lines in Table 1. The lower strip of spectrum is a different contrast print to show lines in weak ultraviolet region.